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ABSTRACT

Reported is a study of two instructional strategies: (1) the placement of key questions in text materials, and (2) the use of prescriptive feedback to direct students who missed text questions to appropriate remedial work. Learning that resulted from these two techniques was examined relative to achievement, time-on-task, and efficiency. Undergraduate volunteers (N=150) were randomly assigned to one of five treatments which varied by complexity of feedback provided. After pretesting, subjects completed a self-paced text unit on soil ecology, followed by a posttest and delayed retention test. Repeated measures analysis of variance revealed that significant differences in instructional time and learning efficiency were not linearly related to complexity of feedback. Differences between group and achievement were marginally significant. (Author/WB)

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LEARNING ENVIRONMENTAL SCIENCE FROM TEXT AIDED BY A DIAGNOSTIC AND PRESCRIPTIVE INSTRUCTIONAL STRATEGY

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ABSTRACT

Learning from text aided by information-processing techniques of embedded questions and increasingly complex prescriptive feedback was examined relative to achievement, time-on-task, and efficiency. Undergraduates (n=150) were randomly assigned to one of five treatments which varied along a feedback complexity range. After pretesting, Ss completed a self-paced text unit on soil ecology, followed by a posttest and delayed retention test.

Significant differences in instructional time and learning efficiency were observed which were not linearly related to feedback complexity. Between group and achievement differences were marginally significant.

Knowledge of human information processing and/or how to apply it to learning from text requires-further refinement.

LEARNING ENVIRONMENTAL SCIENCE FROM TEXT AIDED BY A DIAGNOSTIC AND PRESCRIPTIVE INSTRUCTIONAL STRATEGY

The processes by which a student acquires knowledge using the medium of textbooks still remain speculative, even though the textbook industry has enjoyed the devotion of educators (Berkowitz, 1978). Students may read every line of text, skim a page, review what is read or drift off to sleep. The activities which a student engages in when confronted with the text help to determine what is learned, regardless of content (Anderson, 1970). An alternative view considers the student as a passive receptacle whose learning is directly determined by the instructional stimulus. The former view of the student as an active agent in learning seems to be more plausible (Anderson, 1970).

Rothkopf's (1965) notion of how students learn from text suggests that the instructional materials (nominal stimuli) are manipulated by the instructor. The student processes the stimuli identified by the instructor. Those which are attended to are translated into effective stimuli with the end result of the student being able to perform successfully on a learning task.

Several theorists have posed that learning from printed material occurs by a rapid analysis of stimuli at several processing or encoding stages (Anderson, 1971; Craik & Lockhart, 1972; Selfridge & Neisser, 1960; Sutherland, 1968; Treisman, 1964). The first or perceptual encoding stage is the most basic with the shortest memorial life. The

phonological encoding stage is considered to be the major form of representation in short-term memory. The third stage, which is the principal form of long-term memory storage, is semantic encoding (Anderson et al., 1975). Craik and Lockhart (1972) have noted that the primary stages focus on the physical and sensory features of the text while the final stage emphasizes the match between the text and abstractions stored in memory from prior learning.

A by-product of the processing analysis is the memory trace. The persistence of the memory trace has been shown to be a function of the depth of processing. The deeper processing produces traces with more endurance (Morton, 1970). In an applied context this suggests that a student would process textual information into long-term storage if it were semantically encoded. The information would not get into long-term storage if it were processed at a shallower level. As yet, however, minimum thresholds of cognitive processing for semantic encoding of verbal materials have not been established. The research of Bobrow (1970), Anderson et al. (1975) and Zimmer (1978) have supported this interpretation of the depth of processing theory.

Several lines of research have indicated that meaningful processing facilitates learning (Anderson, 1970, Anderson, Goldberg and Hidde, 1971, Bobrow and Bower, 1969). These processing activities have been alternately identified as attention and cognition or information processing. Rothkopf (1965) has devised the term mathemagenic behaviors to describe these processing activities which "give birth to learning." Mathemagenic behaviors are those activities of the learner which turn nominal stimuli into effective stimuli which in turn determine what is learned.

Rothkopf's conceptualization of mathemagenic behaviors has been the impetus for a sizable amount of research in the management of learning activities. Specifically, researchers have attempted to manipulate instructional materials to engage learners in deep cognitive processing. These manipulations have taken the forms of textual organization, orienting directions, behavioral objectives and questions interspersed with text (Frase, 1975).

Merrill and Boutwell (1973) have identified two other manipulations of learning from text: prompting and feedback. These are forms of mathemagenic information. Kulhavy (1977) has defined feedback as any of the various ways that may be used to inform a learner about the correctness of an instructional response.

Feedback has been a popular research topic; however, few studies have investigated its effects using real instructional materials in an instructional as opposed to laboratory environment (Anderson et al., 1975). As a result, the generalizability of laboratory findings has been limited. Real instruction, defined as text materials designed for use in a classroom setting rather than artificial instruction designed for laboratory use (Estes, 1977), was used by the present study in a computer-assisted environment.

Kulhavy, Yekovich and Dyer (1976) have noted that feedback research has also been limited by the lack of sophisticated instructional delivery systems. The present study incorporated recent and powerful technology utilizing a computer to make study assignments from an item pool and to score the criterion tests. Latent image score sheets were also used to provide instant feedback. The instructional material was

one unit of a text designed to teach soil ecology to high school students.

Rationale

The work of researchers such as Rothkopf (1970), Anderson et. al (1975), and others confirm the instructional value of placing key questions in text. One explanation of these results is that the questions elicit a deep processing of the textual material. Information processing researchers (e.g., Eysenck, 1979) argue for levels or depth of processing to facilitate encoding, the passage of information from short term-memory to long-term memory storage.

Managerially, questions can be employed to assess knowledge status (diagnosis) to determine the subsequent path through instructional activities (prescription). Kulhavy (1977) has argued that the fact of missing a test item "sensitizes" one's processing mechanism to correct the error.

In the present study questions were embedded in a text; they were designed to function mathemagenically and to operate diagnostically and prescriptively when error occurred.

The argument has been made that behavioral objectives, pictures and visuals can also serve to stimulate information processing. The question arises: what role does interaction feedback play in learning from text when the feedback is varied with knowledge of results and prescriptions?

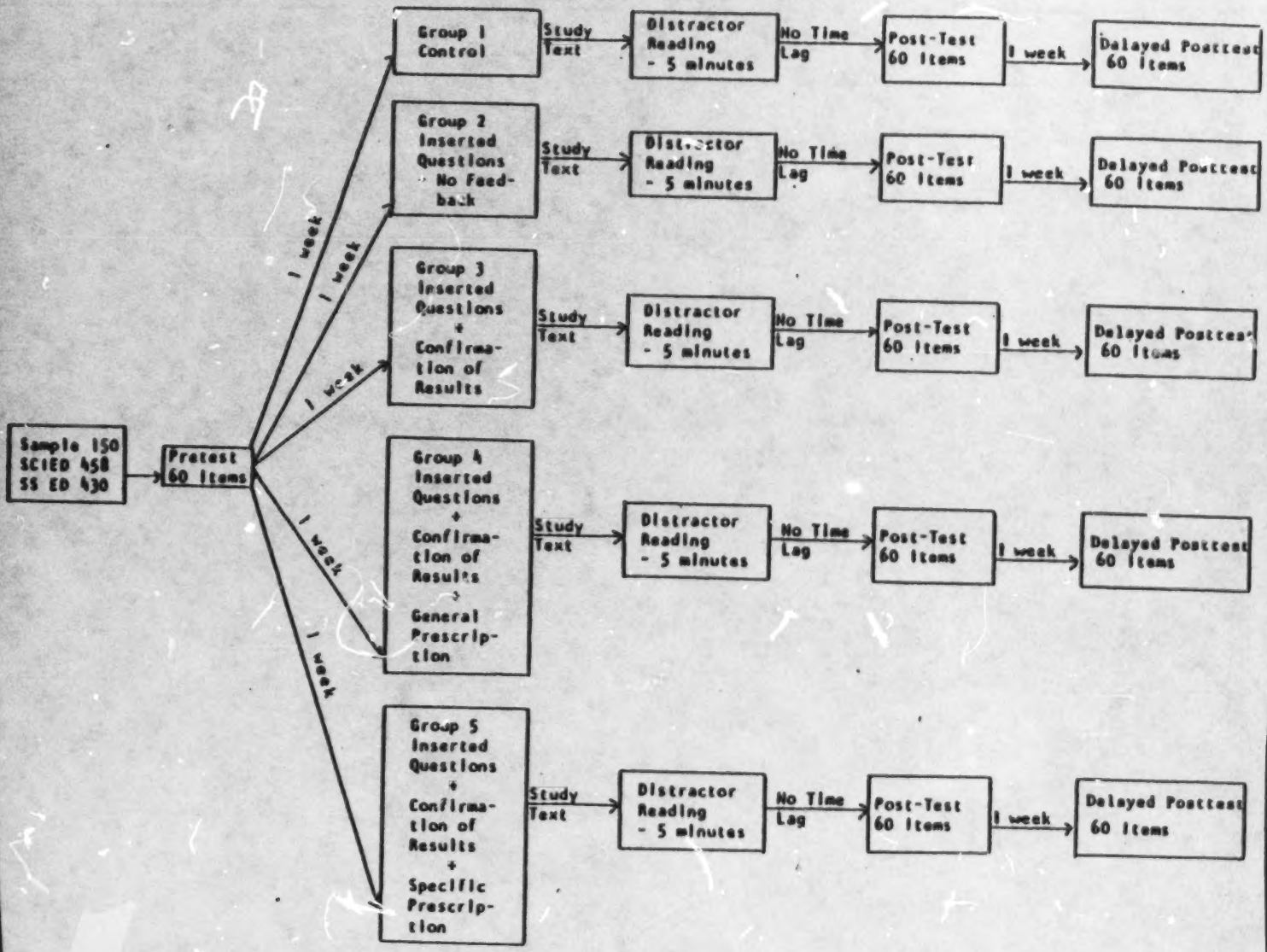
Procedures

Depth-of-processing techniques based on a diagnostic and prescriptive instructional model were developed. While reading a passage of text on soil ecology, subjects responded to embedded questions. Failure to master questions resulted in one of several prescriptions which directed subjects

back to selected components of the text. The five different treatment groups experienced increasing levels of feedback to be processed: 1) reading only, 2) EQ (embedded questions) + no COR (Confirmation of results) + no prescription; 3) EQ + COR + no prescription; 4) EQ + COR + general prescription (i.e., instructional objective); 5) EQ + COR + specific prescription (i.e., page.)

Assignment of one hundred fifty (150) undergraduate volunteers to four treatment and control groups was done randomly. The self-paced instruction which followed an achievement pretest required approximately one hour to complete. A five-minute distractor reading passage was assigned between the instruction and posttest to offset short-term memory effects.

A 3 X 5 repeated measures analysis was conducted on testing (pre, post, and delayed retention) and five treatment groups. Test reliability was estimated at 0.89. In addition to an achievement criterion, time-on-task and instructional efficiency (achievement score, unadjusted for pretest variation, divided by time-on-task) were computed.



Schematic representation of the design of the study.

Results

A significant difference between treatment groups for time-on-task was observed. $F(4, 145)=10.6$, $p<0.5$. The specific prescription group spent less time than did the general prescription group. Apriori contrasts revealed that the control group spent less time than the weighted average of the other four groups and the EQ only groups used less time than the weighted average of groups three, four and five.

The treatment main effect did not reach significance, F (4, 145) = 2.2, $p < .07$. Mean scores on all three tests for groups one and five tended to be higher than for the remaining groups. The test main effect was significant, F (2,290) = 252.4 $p < .05$ with mean score favoring immediate and delayed post-test scores over pretest scores.

H1.1 Achievement

While the repeated measures of analysis of variance on the achievement test (Table 1) did not reach significance, F (4, 145) = 2.2, $p<0.07$, the within subjects analysis yielded a non-significant effect for treatment x test interaction but a significant main effect for tests as indicated in Table 1, F (2,290) = 252.39, $p<0.05$.

Table 1

3x5 Analysis of Variance Summary Table on Pretests, Posttests, Delayed Posttests of Achievement Scores (Repeated Measures)

Source	SS	df	MS	F	Probability
Between Subjects					
Treatments	902.92	4	225.73	2.22	0.07
Error	14771.50	145	101.87		
Within Subjects					
Tests	7794.65	2	3897.33	252.39	0.00*
Interaction	93.21	8	11.65	0.76	0.64
Error	4478.13	290	15.44		

* $p < .05$

The gain that occurred was between pretest and posttest and pretest an delayed posttest (see Table 2). Table 2 shows that there were significant differences between posttest (SE-2) and pretest (SE-1), t (290) = 19.95, $p < 0.05$, and between delayed posttest (SE-3) and pretest (SE-1), t (290) = 18.93, $p < 0.05$. There were no significant differences between posttest (SE-2) and delayed posttest (SE-3), t (290) = 1.01, $p > 0.05$.

Table 2

Pairwise Contrasts for Pretest (SE-1), Posttest (SE-2) and Delayed Posttest (SE-3) (t-tests)

T - T	Difference	Obtained t Statistic	df value	Critical Value of t
SE-2 - SE-1	9.05	19.95	290	2.36
SE-2 - SE-3	0.46	1.01	290	1.97
SE-3 - SE-1	8.59	18.93	290	1.97

Although the interaction effect was not significant, the a priori hypotheses were tested via complex contrasts among means (COMCON). This program computes confidence intervals and tests complex contrasts involving more than two means. The Bonferroni t was used in order to control for family-wise Type I error rate (FWI), at less than alpha. The Bonferroni solutions are generally superior in power to alternative methods that control FWI (Games, 1971). To test the first hypotheses, group 4 was compared with group 5 on mean scores of achievement (posttest SE-2, delayed posttest SE-3) (see Table 3 for cell means and standard deviations).

Table 3

Table of Cell Means and Standard Deviations for Five Treatment Groups on Five Criterion Variables

Treatment Group	n	Criterion Variables									
		SE-1		SE-2		SE-3		Time[a]		Efficiency	
		$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.
1	30	34.5	6.98	43.3	7.17	43.4	5.80	34.87	6.81	1.29	0.35
2	30	32.3	6.40	41.7	6.19	41.7	5.85	38.43	7.87	1.11	0.27
3	30	32.3	5.37	40.2	7.45	39.2	8.04	39.00	10.41	1.09	0.31
4	30	31.6	6.28	40.5	6.56	40.1	6.72	48.53	9.25	0.86	0.18
5	30	33.9	8.02	44.4	6.33	43.4	5.99	43.13	8.61	1.06	0.24
Column Total	150	32.9		42.0		41.5		40.79		1.08	

[a] In minutes

The t-test for complex contrasts (see Table 4) conducted on the mean criterion posttest (SE-2) performance of groups 4 and 5 yielded a t (145) = -1.50, $p > 0.05$, which did not permit rejection of the null hypothesis for the posttest. These nonsignificant results failed to support hypotheses H1.1. For the delayed posttest (SE-3), no significant differences were found among the means when a t-test for complex contrasts was conducted, t (145) = -1.27, $p > 0.05$ (see Table 5).

Table 4

Complex Contrasts Among Posttest Means (SE-2) of Five Groups on Achievement

Comparison[a]	Sample Contrast PSI Hat	Est. Standard Error of PSI Hat	Obtained t or t'	Prob. of t (two-tailed)
1. $\bar{X}_1 \neq \bar{X}_2+\bar{X}_3+\bar{X}_4+\bar{X}_5$	1.60	2.06	0.78	0.44
2. $\bar{X}_2 \neq \bar{X}_3+\bar{X}_4+\bar{X}_5$	0.00	2.13	0.00	1.00
3. $\bar{X}_3 \neq \bar{X}_4+\bar{X}_5$	1.50	2.61	0.58	0.57
4. $\bar{X}_4 \neq \bar{X}_5$	-3.90	2.61	-1.50	0.14

[a]See Figure 2 on page 78.

Table 5

Complex Contrasts Among Delayed Posttest Means (SE-3) of Five Groups on Achievement

Comparison	Sample Contrast PSI Hat	Est. Standard Error of PSI Hat	Obtained t or t'	Prob. of t (two-tailed)
1. $\bar{X}_1 \neq \bar{X}_2+\bar{X}_3+\bar{X}_4+\bar{X}_5$	2.29	2.06	1.11	0.27
2. $\bar{X}_2 \neq \bar{X}_3+\bar{X}_4+\bar{X}_5$	0.79	2.13	0.37	0.71
3. $\bar{X}_3 \neq \bar{X}_4+\bar{X}_5$	2.47	2.61	0.95	0.35
4. $\bar{X}_4 \neq \bar{X}_5$	-3.30	2.61	-1.27	0.21

H1.2 Instructional Time-on-Task

A 1x5 analysis of variance (ANOVES) between groups was conducted on the criterion of instructional time-on task (see Table 6). The results revealed a significant treatment effect, F (4,145) = 10.62, $p < 0.05$. It should be noted that the significant F indicates rejection of the null hypothesis among five mean instructional time-on-tasks.

Table 6

1x5 Analysis of Variance Summary Table of Instructional Time-on-Task

Source	SS	df	MS	F	Probability
Between Groups					
Treatments	3199	4	799.69	10.62	0.00*
Error	10916	145	75.28		

* $p < .05$

To test the hypothesis that group 4 would complete the instruction in more time than group 5, complex contrasts (COMCON) was run using equally weighted contrasts for $\bar{X}_4$ and $\bar{X}_5$. The results are found in comparison 4 of Table 7. The mean of group 4 (see Table 3) is significantly higher than the mean of group 5, t (145) = 2.41, $p < 0.05$. Hypothesis H1.2 was supported; group 4 spent significantly more time on the instructional task than group 5.

Table 7

Complex Contrasts Among Means of Five Groups on Instructional Time-on-Task Variable

Comparison	Sample Contrast PSI Hat	Est. Standard Error of PSI Hat	Obtained t or t'	Prob. of t (two-tailed)
1. $\bar{X}_1 \neq \bar{X}_2+\bar{X}_3+\bar{X}_4+\bar{X}_5$	-7.56	1.77	-4.27	0.00
2. $\bar{X}_2 \neq \bar{X}_3+\bar{X}_4+\bar{X}_5$	-4.48	1.83	-2.45	0.02
3. $\bar{X}_3 \neq \bar{X}_4+\bar{X}_5$	0.07	2.24	0.03	0.98
4. $\bar{X}_4 \neq \bar{X}_5$	5.40	2.24	2.41	0.02

H1.3 Instructional Efficiency

A 1x5 analysis of variance (ANOVES) between groups was conducted on the criterion of instructional efficiency (see Table 8). The results revealed a significant treatment effect, F (4,145) = 9.57, $p < 0.05$. To test the hypothesis that group 4 is more efficient than group 5, complex contrasts (COMCON) was run using equally weighted contrasts for $\bar{X}_4$ and $\bar{X}_5$. The results are found in comparison 4 of Table 9. The mean of group 5 (see Table 3) was significantly higher than the mean of group 4, t (145) = -3.65, $p < 0.05$. This difference was opposite to that predicted: group 4 was significantly less efficient than group 5. Hypothesis H1.3 was not supported in the direction it was posed. Table 10 lists the absolute and efficiency indices for groups on posttest (SE-2) scores.

Table 8

1x5 Analysis of Variance Summary Table
on Instructional Efficiency Variable

Source	SS	df	MS	F	Probability
Between Groups					
Treatments	2.90	4	0.72	9.57	0.00*
Error	10.97	145	0.08		

* $p < .05$

Table 9

Complex Contrasts Among Means of
Five Groups on Instructional
Efficiency Variable

Comparison	Sample Contrast PSI Hat	Est. Standard Error of PSI Hat	Obtained t or t'	Prob. of t (two-tailed)
1. $\bar{X}_1 \neq \bar{X}_2+\bar{X}_3+\bar{X}_4+\bar{X}_5$	0.26	0.07	3.90	0.00
2. $\bar{X}_2 \neq \bar{X}_3+\bar{X}_4+\bar{X}_5$	0.10	0.05	1.77	0.08
3. $\bar{X}_3 \neq \bar{X}_4+\bar{X}_5$	0.10	0.07	0.14	0.89
4. $\bar{X}_4 \neq \bar{X}_5$	-0.20	0.05	-3.65	0.00

Table 10

Absolute and Efficiency Indices for Groups on Posttest Scores (SE-2)

Group	Absolute Index	Efficiency Index
1	1.00	1.00
2	0.96	0.88
3.	0.93	0.83
4.	0.94	0.67
5	1.03	0.83

NOTE: The absolute and efficiency indices are compared to the control group index of 1.00.

Pearson Product-Moment Correlations (PPMCR)

A Pearson Product-Moment Correlation using the STPAC program was executed for the five treatment groups on achievement (posttest SE-2, delayed posttest SE-3), instructional time-on-task and instructional efficiency. This was done to determine the relationships (if any) that existed among the criterion variables. The results (see Table 11) are as follows:

Table 11

Pearson Product-Moment Correlation Coefficient (PPMCC) Between Five Groups on Achievement (Posttest SE-2 and Delayed Posttest SE-3), Instructional Time-on-Task and Instructional Efficiency

	Pretest (SE-1)	Posttest (SE-2)	Delayed Posttest (SE-3)	Instructional Time-on-Task	Instructional Efficiency
Pretest (SE-1)		0.56*	0.57*	0.14*	0.30*
Posttest (SE-2)			0.85*	0.14*	0.47*
Delayed Posttest (SE-3)				0.12	0.40*
Instructional Time-on-Task					-0.77*

* $p < 0.05$

Pretest (SE-1)

There was a moderately strong positive correlation (0.56) between pretest scores (SE-1) and posttest scores (SE-2). As pretest (SE-1) scores went up, posttest scores (SE-2) also went up for all groups. There was also a moderately strong positive correlation (0.57) between pretest scores (SE-1) and delayed posttest scores (SE-3). There was a very low positive correlation (0.14) between pretest scores (SE-1) and time. With pretest scores (SE-1) and efficiency, a low positive correlation (0.30) was evident which meant that as efficiency went up, pretest scores went up.

Posttest (SE-2)

There was a high positive correlation (0.85) between posttest scores (SE-2) and delayed posttest scores (SE-3) which indicated good retention. Those high on the posttest (SE-2) were also high on the delayed posttest scores (SE-3) and vica versa. A low positive correlation (0.14) was observed between posttest scores (SE-2) and time which indicated that those who took more time did better. A moderately strong positive correlation (0.47) between posttest scores (SE-2) and efficiency meant that as efficiency increased, posttest scores (SE-2) also increased.

Delayed Posttest (SE-3)

There was a low positive correlation (0.12) between delayed posttest scores (SE-3) and time which meant that those who took more time did better on the delayed posttest (SE-3). There was a moderately strong positive correlation (0.40) between delayed posttest scores (SE-3) and efficiency which meant that as efficiency increased, delayed posttest scores (SE-3) also increased.

Time-Efficiency

There was a strong negative correlation (-0.77) between time and efficiency which meant that as time increased, efficiency decreased overall.

The correlation between delayed posttest scores (SE-3) minus pretest scores (SE-2) and delayed posttest scores (SE-3) minus posttest scores (SE-2) was represented by a low positive value (0.24) which indicated that the amount of retention had a low correlation with overall learning.

Summary

The repeated measures analysis of variance on the achievement test yielded a marginally significant treatment main effect. Within subjects the analysis yielded a nonsignificant effect for treatment x test interaction but a significant main effect for tests. The gain that occurred was between pretest and posttest and pretest and delayed posttest. There were significant differences between posttest (SE-2) and pretest (SE-1) and between delayed posttest (SE-3) and pretest (SE-1). There were no significant differences between posttest (SE-2) and delayed posttest (SE-3).

On instructional time-on-task, the analysis of variance revealed a significant treatment effect. The significant F indicated rejection of the null hypotheses among five mean instructional time-on-tasks.

On instructional efficiency, the analysis of variance revealed a significant treatment effect.

Discussion

The built-in check (effect of embedded questions) did not reveal a mathemagenic effect as was expected. Since subjects had not studied the content before (Soil Ecology) and since their post and delayed scores were significantly higher than pretest scores, we argue that something else operated. Perhaps the information-processing skills of the college juniors were sufficiently well developed or screened so as to short circuit effects of embedded questions.

The overall achievement difference between groups approached but did not reach significance. Inspection of means shows a trend which favored the first and fifth groups (text reading only and text + EQ + COR + specific prescription). Although not definitive, this suggests a lack of linearity between achievement and complexity of diagnostic feedback.

In terms of time-on-task and efficiency, the reading-only group took less time and was thus more efficient. There appears to be a direct relation between time-on-task and complexity on feedback presented. This increased time-on-task had little or no relation to achievement scores, however. Contrary to expectation, the specific prescription group (page) took less time than did the general prescription group (objective). It was felt that the page prescription would enable subjects to quickly assess information relative to their errors.

This study has demonstrated that our knowledge of information processing and/or how to apply it to learning from text requires further refinement. The prospect appears to be reasonably promising.

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